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Short communication

Chemical changes and phosphorus release during decomposition of pea residues in soil

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Abstract

To study C chemistry and nutrient dynamics in decomposing residues and P dynamics at the residue–soil interface, young pea (Pea-Y) and mature pea (Pea-M) residues were incubated in a sandy soil with low P availability. The study was conducted in microcosms in which the residues were separated from the soil by a nylon mesh. Controls consisted of microcosms without residues. Residues and the soil in the immediate vicinity of the nylon mesh were sampled after 5, 15, 28, 42 and 61 days. Residue chemistry was studied by ^{13}C nuclear magnetic resonance (NMR) spectroscopy and determination of C, N and P concentrations. Compared to Pea-M, Pea-Y was characterised by higher N and P concentrations, higher percentage of proteins, esters, fatty acids and sugars, and was more easily decomposable in the first 15 days. Pea-M residues had a greater percentage of cellulose and other polysaccharides than Pea-Y and showed a more gradual loss in dry weight. Differences in C chemistry and N and P concentration between the residues decreased with time. The decomposition of Pea-Y and Pea-M residues resulted in an increase in microbial P in the residue–soil interface compared to the control, but available P was increased only in the vicinity of Pea-Y residues.

Keywords: C chemistry; ^{13}C NMR; Decomposition; Microbial biomass P; P mineralisation; Plant residues; Residue–oil interface

Decomposition of plant residues is the microbially mediated progressive breakdown of organic material into C (biomass or CO_2) and other nutrients (Kumar and Goh, 2000). Crop residues decompose into two distinct phases, an initial rapid phase, in which about 70% of C initially present in the residues is lost as CO_2, followed by a slower phase during which the more resistant fraction is decomposed (Wang et al., 2004). Immature plant residues with a high concentration of water-soluble compounds such as sugars, amino acids and organic acids are decomposed more rapidly than mature material, which contain a higher proportion of resistant compounds such as cellulose, lignin, phenols or waxes.

Inorganic P (P_i) released from residues may come from soluble P_i in the residues and from mineralisation of organic P. Jones and Bromfield (1969) reported that 40–60% of total P in a range of grasses and legumes was present as inorganic P and contributed to the immediate release of P after incorporation of residues into soil. In the later stages of decomposition, P is released from residues more slowly by mineralisation of organic P compounds.

Using microcosms with a thin layer of residues separated from the soil by a nylon mesh, the aims of the present study were to determine temporal changes in residue C chemistry, C, N and P concentration as well as labile P pools at the residue–soil interface during decomposition of young and mature pea residues.

Soil samples were taken in March 2004 from a P fertilisation trial on a Calcarosol (Isbell, 1996) at the Mallee Research Station in Walpeup, Victoria, Australia. The field experiment was started in 1940, initially with a fallow–wheat–oats rotation and from 1960 onwards a fallow–wheat rotation (McClelland, 1968). The treatment chosen for the experiment received no P fertiliser since the

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start of the field trial. The soil had the following properties: clay 12%, sand 81%, silt 7%, pH 6.4, total organic C 2.9 mg kg^{-1}, total P 74 mg kg^{-1}, resin-extractable P 3.6 mg kg^{-1}.

Shoot residues from field-grown pea (Pisum sativum L.) at two different growth stages were chosen: Pea-Y (flowering) and Pea-M (mature). The plant material was air-dried and ground to particle size $\leqslant$5 mm.

The microcosms were a modification of the method used by Kandeler et al. (1999). Caps of PVC tubes (height 20 mm, diameter 70 mm) were filled with 80 g of dry soil and the soil gently pressed. Fine nylon mesh (0.1 mm × 0.8 mm) was cut into circles with a diameter of 85 mm and placed over the soil to cover the open side of each of the caps. One gram of ground pea residues was placed between two layers of mesh. The two caps were held together with rubber bands. The microcosms were incubated at 25 °C in the dark. The moisture content was adjusted every 10 days. Sampling was performed after 5, 15, 28, 42, and 61 days of incubation. There were four replicates per treatment. At each sampling, the two PVC caps were carefully separated from each other, and the two layers of mesh with the residues in between gently removed. The residues were frozen at −80 °C for at least 2 h before they were freeze-dried for at least 3 days. Resin-extractable P and microbial P were measured in a thin layer of soil collected 1–2 mm from the mesh.

For total P, the soils were digested in 6:1 HNO_3:$HClO_4$. The concentration of P in the residues was determined by combustion at 550 °C for 4 h followed by dissolution of the ash in 20% HCl. The P concentration in all solutions was measured colorimetrically (Murphy and Riley, 1962). Total C in the soil and C and N in the residues were determined by dry combustion on a LECO2000 CN Analyzer.

Solid-state ^{13}C magic angle spinning (MAS) nuclear magnetic resonance (NMR) spectra were acquired on the pooled composite of the four replicates of each treatment at each sampling time. Spectra were acquired at a ^{13}C frequency of 50.3 MHz on a Varian Unity 200 spectrometer, using a 1-ms contact time and a 4-s recycle delay; 1000 scans were collected for each spectrum.

Resin-extractable and microbial P were determined by extraction of moist soil with anion exchange membranes (Kuono et al., 1995). Microbial P was calculated as the difference of P extracted with and without liquid hexanol fumigation.

Residue dry weight as a proportion of initial residue dry weight was significantly lower for Pea-Y residues than for Pea-M residues throughout the incubation period (Fig. 1a). After 5 days, 54% of the original dry weight was lost from Pea-Y residues compared to 29% from Pea-M residues. The decrease in dry weight continued from d5 to d15 but was less pronounced than in the first 5 days, and it proceeded at an even slower rate in the period after d15, when dry weight loss was more pronounced in Pea-M than in Pea-Y residues.

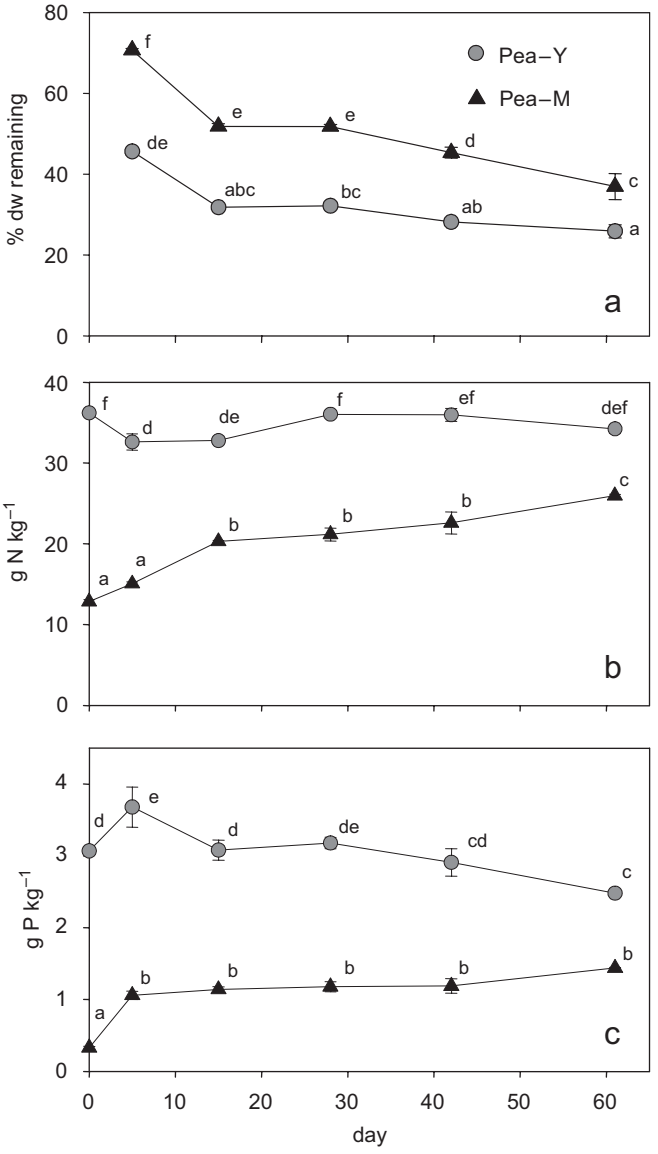

Fig. 1. Percentage dry weight remaining (a) and N (b) and P concentrations (c) of young pea (Pea-Y) or mature pea residues (Pea-M) over 61 days ($n = 4$). The "d0" values refer to residues before incubation. Different letters indicate significant differences ($P \leqslant 0.05$).

The C concentration was similar in both residues and did not change significantly in the first 42 days, but on d61 it was significantly lower than on d5 in both residues (data not shown). For Pea-Y residues, the N concentration fluctuated between 33 and 36 g N kg^{-1} dry matter, without showing a clear time trend (Fig. 1b). The N concentration in Pea-M residues increased over time but always remained significantly lower than in Pea-Y residues.

The P concentration in the Pea-Y residues was always significantly higher than in the Pea-M residues, the difference being greatest in the original residues (Fig. 1c). The P concentration in the Pea-Y residues on d5 was higher than on d0, but then decreased to the original values until d42. On d61, the P concentration in the Pea-Y residues was significantly lower than in the first 15 days.